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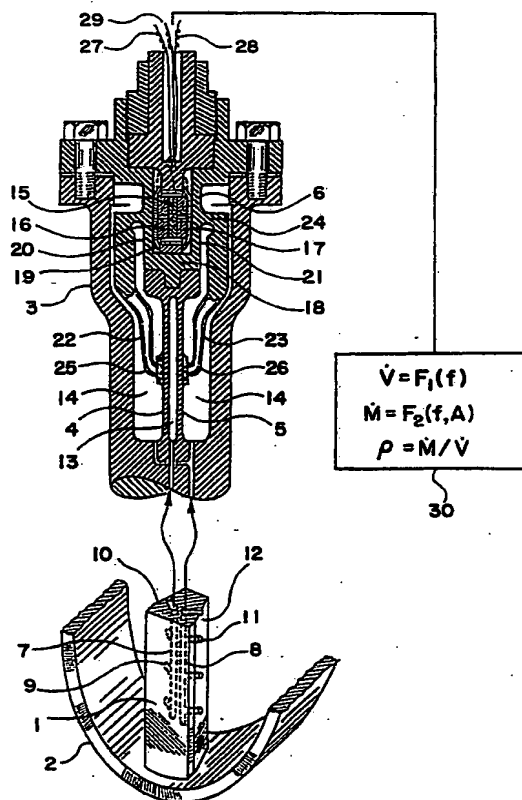
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(54) Title: NOISE REJECTING VORTEX FLOWMETER

(57) Abstract

A vortex flowmeter comprises a vortex generating bluff body (1), a first pressure compartment (13) with two end walls provided by two thin planar members (4 and 5), which first pressure compartment (13) receives fluid pressure existing at a first side surface (10) of the bluff body (1), a second pressure compartment (14) straddling the combination of the two thin planar members (4 and 5) and the first pressure compartment (13), which second pressure compartment (14) receives fluid pressure existing at a second side surface (12) of the bluff body (1), and a transducer (3) converting relative flexural vibration between the two thin planar members (4 and 5) into a fluctuating electrical signal representing vortex shedding from the bluff body (1).



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- 1 -

NOISE REJECTING VORTEX FLOWMETER

This invention relates to a vortex flowmeter that determines the volume flow rate of a fluid as a function of the frequency of vortex shedding, which vortex flowmeter has an optional feature that determines the mass flow rate of the fluid as a function of the frequency of vortex shedding and the amplitude of fluctuating fluid dynamic force created by the vortex shedding phenomenon and determines the density of the fluid as the ratio of the mass flow rate to the volume flow rate of the fluid.

Under a carefully controlled laboratory condition wherein the noise created by the structural vibration of the flowmeter body is kept at the minimum level and the fluid dynamic force created by the vortex shedding phenomenon is amplified to the maximum level, a well designed vortex flowmeter is capable of measuring air flow as low as 1 meter per second and water flow as low as 0.05 meter per second. The performance of an industrial vortex flowmeter can approach the standard set under the carefully controlled laboratory condition when the industrial vortex flowmeter is equipped with an optimized noise rejecting vortex sensor and the fluid dynamic force created by the vortex shedding phenomenon is detected in a highly amplified form. The present invention teaches such a high performance vortex flowmeter.

The primary object of the present invention is to provide a vortex flowmeter that detects the vortex shedding from a bluff body of an elongated cylindrical shape disposed across a fluid stream by detecting a relative flexural deflection between two thin planar members or diaphragms separating a first pressure compartment therebetween from a second pressure compartment straddling the two thin planar members and the first pressure compartment, wherein the first pressure compartment receives the fluid pressure existing at a first side surface of the bluff body and the second pressure compartment receives the fluid pressure existing at a second side surface of the bluff body opposite to the first side surface thereof.

Another object is to provide the vortex flowmeter described in the above-presented primary object of the present invention, wherein a piezo electric relative motion sensor with two vibration sensing

SUBSTITUTE SHEET

- 2 -

1 elongated members respectively transmitting the flexural vibration
2 of the two thin planar members to a piezo electric disc element
3 converts the relative flexural vibration between the two thin planar
4 members into an alternating electrical signal representing the vortex
5 shedding from the bluff body.

6 A further object is to provide the vortex flowmeter described in
7 the primary object of the present invention, wherein a capacitive
8 relative motion sensor generating a fluctuating electrical signal
9 related to the electrical capacitance between the two thin planar
10 members converts the relative flexural vibration between the two thin
11 planar members into an alternating electrical signal representing the
12 vortex shedding from the bluff body.

13 Yet another object is to provide the vortex flowmeter that
14 determines the volume flow rate of fluid as a function of the frequency
15 of the alternating electrical signal generated by the piezo electric or
16 capacitive relative motion sensor.

17 Yet a further object is to provide the vortex flowmeter that
18 determines the mass flow rate of fluid as a function of the frequency
19 and amplitude of the alternating electrical signal generated by the
20 piezo electric or capacitive relative motion sensor, and determines
21 the density of fluid as the ratio of the mass flow rate to the volume
22 flow rate of fluid.

23 These and other objects of the present invention will become clear
24 as the description thereof progresses.

25

26 The present invention may be described with a greater clarity and
27 specificity by referring to the following figures :

28 Figure 1 illustrates an embodiment of the vortex flowmeter of the
29 present invention employing two thin planar members constituting the
30 end walls of two pressure compartments and a piezo electric relative
31 motion sensor detecting relative flexural vibration between the two
32 thin planar members.

33 Figure 2 illustrates an embodiment of the piezo electric disc
34 element and the noise cancelling electric circuit included in the
35 piezo electric relative motion sensor.

36 Figure 3 illustrates another embodiment of the combination of the
37 two thin planar members constituting the end walls of the two pressure
38 compartments and a piezo electric relative motion sensor detecting

- 3 -

1 relative flexural vibration between the two thin planar members.

2 Figure 4 illustrates an embodiment of the combination of the two
3 thin planar members constituting the end walls of the two pressure
4 compartments and a capacitive relative motion sensor detecting
5 relative flexural vibration between the two thin planar members.

6

7 In Figure 1, there is illustrated an embodiment of the vortex
8 flowmeter of the present invention comprising a vortex generating
9 bluff body 1 of an elongated cylindrical shape, that is disposed at
10 least partially across a fluid stream moving through a conduit 2, and
11 a transducer 3 including two thin planar members 4 and 5 constituting
12 the end walls of two pressure compartments and a piezo electric
13 relative motion sensor 6 detecting relative flexural vibration between
14 the two thin planar members 4 and 5. The bluff body 1 has two pressure
15 transmitting holes 7 and 8 disposed therethrough following the length
16 of the bluff body 1, wherein the first hole 7 has one or more openings
17 9 open to a first side surface 10 of the bluff body 1, while the
18 second hole 8 has one or more openings 11 open to a second side
19 surface 12 of the bluff body 1 opposite to the first side surface 10
20 thereof. The transducer 3 has a first pressure compartment 13 disposed
21 intermediate the two thin planar members 4 and 5 respectively
22 constituting the two opposite end walls thereof, and a second pressure
23 compartment 14 straddling the combination of the two thin planar
24 members 4 and 5, and the first pressure compartment 13. The first
25 pressure transmitting hole 7 with one extremity open to the first side
26 surface 10 of the bluff body 1 has the other extremity open to the
27 first pressure compartment 13, while the second pressure transmitting
28 hole 8 with one extremity open to the second side surface 12 of the
29 bluff body 1 has the other extremity open to the second pressure
30 compartment 14. The piezo electric relative motion sensor 6 has a
31 piezo electric disc element 15 that includes two sets of split
32 electrodes 16 and 17 respectively disposed on the two opposite sides
33 of the piezo electric disc element 15, which combination of the piezo
34 electric disc element and the electrodes is disposed within a closed
35 cavity of the transducer container vessel 18 in a parallel relationship
36 to the plane of symmetry located intermediate the two thin planar
37 members 4 and 5. The piezo electric disc element 15 extends across the
38 reference plane perpendicular to the plane of symmetry, and each of

SUBSTITUTE SHEET

- 4 -

1 the two sets of electrodes 16 and 17 disposed on each of the two
2 opposite sides of the piezo electric disc element 15 is split along
3 the reference plane. The stacked combination of the piezo electric
4 disc element 15 and the two sets of split electrodes 16 and 17, that
5 is wrapped up by an electrically insulating dielectric wrapper 19,
6 is disposed intermediate two opposite thin walls 20 and 21 of the
7 closed cavity of the transducer container vessel 18 in a compressed
8 relationship therebetween. A pair of elongated vibration sensing
9 members 22 and 23 extending towards a common direction are respectively
10 disposed next to the two opposite thin walls of the closed cavity,
11 wherein the first angled extremity of each of the two elongated
12 vibration sensing members 22 and 23 is anchored to a reinforcing rib
13 24 extending across each of the two opposite thin walls 20 and 21
14 along the reference plane, while the over-hanging second extremities
15 25 and 26 are under pressurized contact respectively with the two thin
16 planar members 4 and 5. The lead wires originating from various
17 electrodes included in the two sets of split electrodes 16 and 17
18 extend out of the transducer container vessel 18.

19 The fluid pressures respectively existing at the two opposite side
20 surfaces 10 and 12 of the bluff body 1 fluctuate in an alternating mode
21 therebetween as the vortices are shed from the two opposite side
22 surfaces 10 and 12 of the bluff body 1 in an alternating mode. The two
23 alternatively fluctuating fluid pressures respectively transmitted to
24 the two pressure compartments 13 and 14 create a relative flexural
25 vibration between the two thin planar members 4 and 5, which relative
26 flexural vibration in turn alternatively compresses and decompresses
27 the two opposite halves of the piezo electric disc element 15
28 respectively located on the two opposite sides of the reference plane
29 defined by the two reinforcing ribs 24 respectively included in the
30 two opposite thin walls of the closed cavity housing the transducer
31 elements. The electromotive forces generated by the two opposite halves
32 of the piezo electric disc element 15 respectively located on the two
33 opposite sides of the reference plane are transmitted through two of
34 the three lead wires 27, 28 and 29, while the third lead wire grounds
35 the electrodes which are not connected to the two lead wires. It should
36 be noticed that the construction of the transducer 3 has a geometry
37 that is symmetric about the plane of symmetry located intermediate the
38 two thin planar members 4 and 5 and, consequently, the inertia force

SUBSTITUTE SHEET

- 5 -

1 created by any structural vibration of the transducer 3 and experienced
2 by all component elements in the transducer 3 is symmetric about
3 the plane of symmetry, while the differential pressure forces across
4 the two thin planar members 4 and 5 created by the vortex shedding
5 from the bluff body 1 are antisymmetric about the plane of symmetry.
6 By using a simple electric circuit exemplified by the embodiment shown
7 in Figure 2, the electrical signal generated by the symmetric component
8 of the forces can be rejected, and the electrical signal generated by
9 the antisymmetric component of the forces can be selectively extracted
10 from the transducer 3. Consequently, the transducer 3 provides an
11 alternating electrical signal generated exclusively by the vortex
12 shedding from the bluff body 1, which alternating electrical signal is
13 substantially free of the noise created by the structural vibration of
14 the transducer 3. The frequency of such an alternating electrical
15 signal is the same as the frequency of the vortex shedding from the
16 bluff body 1, and the amplitude thereof is proportional to the fluid
17 density times a power function of the fluid velocity (typically a
18 square function for a well designed pressure openings included in the
19 bluff body). A data processor 30 determines the fluid velocity U or the
20 volume flow rate of fluid \dot{V} as a function of the frequency f of the
21 alternating electrical signal provided by the transducer 3, and
22 determines the mass flow rate of fluid \dot{M} as a function of the frequency
23 f and the amplitude A of the alternating electrical signal provided by
24 the transducer 3. The data processor 30 can also determine the fluid
25 density as the ratio of the mass flow rate \dot{M} to the volume flow rate
26 \dot{V} . It should be understood that, in an alternative design, the
27 reinforcing ribs 24 included in the two opposite thin walls 20 and 21
28 of the closed cavity housing the piezo electric disc element 15 may be
29 omitted and the angled first extremities of the two elongated
30 vibration sensing members 22 and 23 may be anchored directly to the two
31 opposite thin walls 20 and 21. The transducer 3 and the bluff body 1
32 may be constructed into a single integral structure, or connected to
33 one another rigidly by means of a mechanical coupling or welding.
34 Of course, the transducer 3 and the bluff body 1 may be constructed in
35 a structurally separate and independent arrangement and connected to
36 one another by a pair of flexible or rigid tubings transmitting the
37 fluid pressures existing at the two opposite side surfaces 10 and 12 of
38 the bluff body 1 to the two pressure compartments 13 and 14,

SUBSTITUTE SHEET

- 6 -

1 respectively. The illustrative embodiment shown in Figure 1 as well as
2 the other embodiments shown in Figures 3 and 4 can be used to construct
3 an in-line type or an insertion type vortex flowmeter.

4 In Figure 2, there is illustrated an embodiment of the stacked or
5 layered combination of the piezo electric disc element 15 and the two
6 sets of split electrodes 16 and 17 respectively included in the two
7 opposite sides of the piezo electric disc element 15. In the particular
8 illustrative embodiment, one of the first pair of split electrodes 16
9 located on one side of the piezo electric disc element 15 and on
10 one side of the reference plane including the demarcation line between
11 the first pair of split electrodes 16 is connected to a first amplifier
12 31 by means of the lead wire 27, while one of the second pair of split
13 electrodes 17 located on the other side of the piezo electric disc
14 element 15 and on the other side of the reference plane is connected to
15 a second amplifier 32 by means of the lead wire 28, wherein the two
16 amplifiers 31 and 32 include a signal level balancing means 33 such as
17 one or more variable resistors. The electrodes not connected to the
18 amplifiers 31 and 32 are grounded by means of the lead wire 29. The
19 antisymmetric component of the forces experienced by the component
20 elements in the transducer 3 alternatively compresses and decompresses
21 the two opposite halves of the piezo electric disc element 15
22 respectively located on the two opposite sides of the reference plane,
23 while the symmetric component of the forces experienced by the
24 component elements of the transducer 3 compresses or decompresses both
25 of the two opposite halves of the piezo electric disc element 15.

26 When the piezo electric disc element 15 is polarized in the same
27 direction over both of the two opposite halves thereof, the anti-
28 symmetric component of the forces created by the vortex shedding from
29 the bluff body 1 produces two alternating electrical signals of the
30 same phase (same sign) respectively from the two electrodes connected
31 to the two amplifiers 31 and 32, which two alternating electrical
32 signals are additively combined to provide the alternating output
33 electrical signal 34 representing the vortex shedding from the bluff
34 body 1, while the symmetric component of the forces created by the
35 structural vibration of the transducer 3 produces two alternating
36 electrical signals with 180 degree phase angle difference therebetween
37 (opposite sign) respectively from the two electrodes connected to the
38 two amplifiers 31 and 32, which two alternating electrical signals of

SUBSTITUTE SHEET

- 7 -

1 opposite signs are cancelled out in the additive combination process
2 wherein the signal balancing means 33 is set to a value that exactly
3 balances the amplitudes of the two alternating electrical signals of
4 opposite signs respectively amplified by the two amplifiers 31 and 32.
5 The alternating output electrical signal 34 is supplied to the data
6 processor 30 included in the embodiment shown in Figure 1, that
7 determines the volume flow rate of fluid and/or the mass flow rate
8 as well as the density of the fluid. It should be mentioned that, in
9 an alternative design, two split electrodes located on the same side
10 of the piezo electric disc element and respectively on the two
11 opposite sides of the reference plane may be connected to an inverting
12 amplifier and a noninverting amplifier in a parallel arrangement,
13 respectively, wherein the noise is cancelled therebetween by means of
14 the signal level balancing means between the two amplifiers, or the
15 two split electrodes may be connected to two opposite terminals of
16 an electrical circuit in a series arrangement, wherein the alternating
17 output electrical signal is obtained by a differential combination
18 and the noise is cancelled by an additive combination. In another
19 alternative design, a piezo electric disc element with the two opposite
20 halves respectively polarized in two opposite directions may be
21 employed in conjunction with various arrangements of the electrodes,
22 wherein the alternating output electrical signal is obtained and the
23 noise is cancelled by means of additive combination process using a
24 parallel circuit or by means of differential combination using a series
25 circuit.

26 In Figure 3, there is illustrated another embodiment of the piezo
27 electric transducer operating on the same principles as those
28 described in conjunction with Figures 1 and 2. In this illustrative
29 embodiment, a pair of piezo electric motion sensors 35 and 36 are
30 employed in place of the single piezo electric relative motion sensor
31 6 included in the embodiment shown in Figure 1. Each of the two piezo
32 electric motion sensors 35 and 36 comprises the stacked or layered
33 combination of the piezo electric disc element 37 sandwiched between
34 the two sets of split electrodes 38 and 39, which combination is
35 sandwiched between the two insulating discs or layers 40 and 41.
36 This stacked or layered combination of the transducer disc elements
37 are disposed in a closed cavity of the transducer container vessel 42
38 in a compressed relationship against a thin end wall 43 of the closed

- 8 -

1 cavity housing the transducer elements. An elongated vibration sensing
2 members 44 with one extremity anchored to the reinforcing rib 45 that is
3 disposed on a reference plane parallel to the plane of symmetry
4 located intermediate the two thin planar members 46 and 47, extends
5 from the thin end wall 43 of the closed cavity. The other extremity
6 of the elongated vibration sensing members 44 of the each of the two
7 piezo electric motion sensors 35 and 36 are under a pressurized contact
8 with each of the two thin planar members 46 and 47 constituting the end
9 walls of the two pressure compartments 48 and 49. It should be noticed
10 that the piezo electric disc element 37 is disposed on a plane parallel
11 to the thin end wall 43 of the closed cavity, which plane is perpen-
12 dicular to the reference plane defined by the reinforcing rib 45.
13 The stacked or layered combination of the transducer disc elements
14 shown in Figure 2, or other modified versions thereof described in
15 conjunction with Figure 2 can be employed in constructing the piezo
16 electric motion sensors 35 and 36. It should be understood that the
17 two electrical signals respectively generated by the two opposite
18 halves of the piezo electric disc element respectively located on the
19 two opposite sides of the reference plane are combined by means of a
20 noise cancelling electrical circuit such as the one shown in Figure 2
21 for each of the two piezo electric motion sensors 35 and 36, and then
22 the two output electrical signals respectively supplied by the two
23 piezo electric motion sensors 35 and 36 are combined again by using a
24 second stage noise cancelling electrical circuit comprising the two
25 amplifiers 50 and 51, and the signal level balancing means 52, which
26 combination provides the alternating output electrical signal
27 representing the vortex shedding from the bluff body. It can be readily
28 realized that an economic version of the transducer providing the
29 alternating output electrical signal representing the vortex shedding
30 from the bluff body can be derived from the embodiment shown in Figure
31 3 by eliminating one of the two piezo electric motion sensors 35 and
32 36, one of the two thin planar members 46 and 47, and one of the two
33 halves of the second pressure compartment 49 straddling the first
34 pressure compartment 48. A vortex flowmeter with such an economized
35 version of the transducer is claimed separately in the claims.

36 In Figure 4, there is illustrated an embodiment of the capacitive
37 transducer that can be employed in place of the piezo electric
38 transducer 3 included in the embodiment shown in Figure 1. In this

SUBSTITUTE SHEET

- 9 -

1 particular embodiment, the two thin planar members 53 and 54
2 constituting the end walls of the two pressure compartments 55 and 56
3 are disposed in a parallel relationship at a close proximity to one
4 another in order to create a large electrical capacitance therebetween.
5 A device 57 measuring the capacitance between the two thin planar
6 members or other electrical variables related to the capacitance
7 provides an alternating or fluctuating output electrical signal 58
8 representing the vortex shedding from the bluff body. The device 57
9 may be an instrument measuring the capacitance, or a detector or
10 demodulator providing an electrical signal representing the envelope
11 of a high frequency alternating electrical signal transmitted through
12 an electrical circuit including a capacitor comprising the two thin
13 planar members 53 and 54, wherein the high frequency alternating
14 electrical signal oscillates at the resonance frequency of the
15 electrical circuit with the two thin planar members under zero relative
16 deflection therebetween. As the amplitude of the high frequency
17 alternating electrical signal changes very sensitively as a function
18 of the relative distance between the two thin planar members 53 and
19 54, the envelope of the high frequency alternating electrical signal
20 provides a fluctuating output electrical signal 58 representing the
21 vortex shedding from the bluff body. Of course, the fluctuating output
22 electrical signal 58 generated by the transducer shown in Figure 4
23 can be readily converted to an alternating output electrical signal
24 representing the vortex shedding from the bluff body by taking out
25 the direct current component therefrom.

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SUBSTITUTE SHEET

- 10 -

1 The embodiments of the invention, in which an exclusive property
2 or privilege is claimed, are defined as follows :

3 1. An apparatus for measuring flow rate of fluid comprising in
4 combination :

5 a) a vortex generator of an elongated cylindrical shape
6 disposed at least partially across a fluid stream,
7 said vortex generator including a first hole with one
8 extremity including at least one opening open to a first
9 side surface of the vortex generator and a second hole
10 with one extremity including at least one opening open to
11 a second side surface of the vortex generator opposite to
12 said first side surface;

13 b) a transducer body including a first pressure compartment
14 with two opposite end walls provided by two thin planar
15 members, and a second pressure compartment straddling the
16 combination of the two thin planar members and the first
17 pressure compartment, wherein the other extremity of the
18 first hole included in the vortex generator is open to
19 the first pressure compartment and the other extremity of
20 the second hole included in the vortex generator is open
21 to the second pressure compartment; and

22 c) a transducer means for converting a relative flexural
23 vibration between the two thin planar members into a
24 fluctuating electrical signal representing vortex shedding
25 from the vortex generator.

26 2. An apparatus as defined in Claim 1 wherein said combination
27 includes means for determining volume flow rate of fluid as a function
28 of frequency of the fluctuating electrical signal.

29 3. An apparatus as defined in Claim 1 wherein said combination
30 includes means for determining mass flow rate of fluid as a function
31 of frequency and amplitude of fluctuation of the fluctuating electrical
32 signal.

33 4. An apparatus as defined in Claim 1 wherein said transducer
34 means comprises a piezo electric relative motion sensor including :

35 a) a transducer container vessel secured to the transducer
36 body and having a closed cavity with two opposite thin
37 walls disposed approximately parallel to a plane of
38 symmetry located intermediate the two thin planar members

- 11 -

- 1 in a parallel relationship;
- 2 b) a piezo electric disc element disposed within the closed
- 3 cavity of the transducer container vessel on a plane
- 4 approximately parallel to said plane of symmetry
- 5 intermediate the two opposite thin walls of the closed
- 6 cavity in a compressed relationship therebetween, said
- 7 piezo electric disc element extending across a reference
- 8 plane perpendicular to said plane of symmetry and
- 9 intersecting with the two opposite thin walls of the
- 10 closed cavity in a perpendicular relationship, and
- 11 including at least two electrodes respectively located
- 12 on two opposite sides of said reference plane;
- 13 c) two elongated vibration sensing members respectively
- 14 disposed next to the two opposite thin walls of the closed
- 15 cavity, each of the two elongated vibration sensing
- 16 members including an angled first extremity disposed on
- 17 said reference plane and secured to each of the two opposite
- 18 thin walls of the closed cavity, and an over-hanging
- 19 second extremity under a pressurized contact with each of
- 20 the two thin planar members; and
- 21 d) means for combining two electrical signals respectively
- 22 supplied by said at least two electrodes, wherein noise
- 23 is cancelled out between the two electrical signals and
- 24 a refined output electrical signal representing vortex
- 25 shedding from the vortex generator is obtained.
- 26 5. An apparatus as defined in Claim 1 wherein said transducer
- 27 means comprises two piezo electric motion sensors, each of said two
- 28 piezo electric motion sensors including :
- 29 a) a transducer container vessel secured to the transducer
- 30 body and having a closed cavity with a thin end wall
- 31 disposed approximately perpendicular to a plane of
- 32 symmetry located intermediate the two thin planar
- 33 members in a parallel relationship;
- 34 b) a piezo electric disc element disposed within the closed
- 35 cavity of the transducer container vessel on a plane
- 36 approximately perpendicular to said plane of symmetry
- 37 in a compressed relationship against the thin end wall
- 38 of the closed cavity, said piezo electric disc element

SUBSTITUTE SHEET

- 12 -

1 extending across a reference plane parallel to said
2 plane of symmetry and intersecting with the thin end wall
3 of the closed cavity in a perpendicular relationship,
4 and including at least two electrodes respectively located
5 on two opposite sides of said reference plane;

6 c) an elongated vibration sensing member extending from the
7 thin wall of the closed cavity, said elongated vibration
8 sensing member including a first extremity disposed on
9 said reference plane and secured to the thin wall of the
10 closed cavity, and an over-hanging second extremity
11 under a pressurized contact with each of the two thin
12 planar members; and

13 d) means for combining two electrical signals respectively
14 supplied by said at least two electrodes, wherein noise
15 is cancelled out between the two electrical signals and
16 a single electrical signal representing flexural
17 vibration of each of the two thin planar members is
18 obtained;

19 wherein said combination further includes means for combining the
20 single electrical signal provided by one of the two piezo electric
21 motion sensor and the single electrical signal provided by the other
22 of the two piezo electric motion sensor, wherein noise is cancelled
23 between said two single electrical signals and a refined output
24 electrical signal representing vortex shedding from the vortex
25 generator is obtained.

26 6. An apparatus as defined in Claim 1 wherein said transducer
27 means comprises means for producing an output electrical signal
28 representing value of electrical capacitance between the two thin
29 planar members as a measure of vortex shedding from the vortex
30 generator.

31 7. An apparatus for measuring flow rate of fluid comprising in
32 combination :

33 a) a vortex generator of an elongated cylindrical shape
34 disposed at least partially across a fluid stream,
35 said vortex generator including a first hole with one
36 extremity including at least one opening open to a first
37 side surface of the vortex generator and a second hole
38 with one extremity including at least one opening open to

- 13 -

- 1 a second side surface of the vortex generator opposite to
2 said first side surface;
- 3 b) a transducer body including a first and second pressure
4 compartment separated by a thin planar member constituting
5 a common end wall of the first and second pressure
6 compartment, wherein the other extremity of the first hole
7 included in the vortex generator is open to the first
8 pressure compartment, and the other extremity of the second
9 hole included in the vortex generator is open to the second
10 pressure compartment; and
- 11 c) a piezo electric motion sensor including :
- 12 1) a transducer container vessel secured to the transducer
13 body and having a closed cavity with a thin end wall
14 disposed approximately perpendicular to the thin planar
15 member;
- 16 2) a piezo electric disc element disposed within the closed
17 cavity of the transducer container vessel on a plane
18 parallel to the thin end wall of the closed cavity,
19 said piezo electric disc element extending across a
20 reference plane approximately parallel to the thin planar
21 member and intersecting with the thin end wall of the
22 closed cavity in a perpendicular relationship, and
23 including at least two electrodes respectively located
24 on two opposite sides of said reference plane;
- 25 3) an elongated vibration sensing member extending from
26 the thin end wall of the closed cavity, said elongated
27 vibration sensing member including a first extremity
28 disposed on said reference plane and secured to the
29 thin end wall of the closed cavity, and an over-hanging
30 second extremity under a pressurized contact with the
31 thin planar member; and
- 32 4) means for combining two electrical signals respectively
33 supplied by said at least two electrodes, wherein noise
34 is cancelled between the two electrical signals and
35 a fluctuating output electrical signal representing
36 vortex shedding from the vortex generator is obtained.
- 37 8. An apparatus as defined in Claim 7 wherein said combination
38 includes means for determining volume flow rate of fluid as a function

SUBSTITUTE SHEET

- 14 -

1 of frequency of the fluctuating output electrical signal.

2 9. An apparatus as defined in Claim 7 wherein said combination
3 includes means for determining mass flow rate of fluid as a function
4 of frequency and amplitude of fluctuation of the fluctuating output
5 electrical signal.

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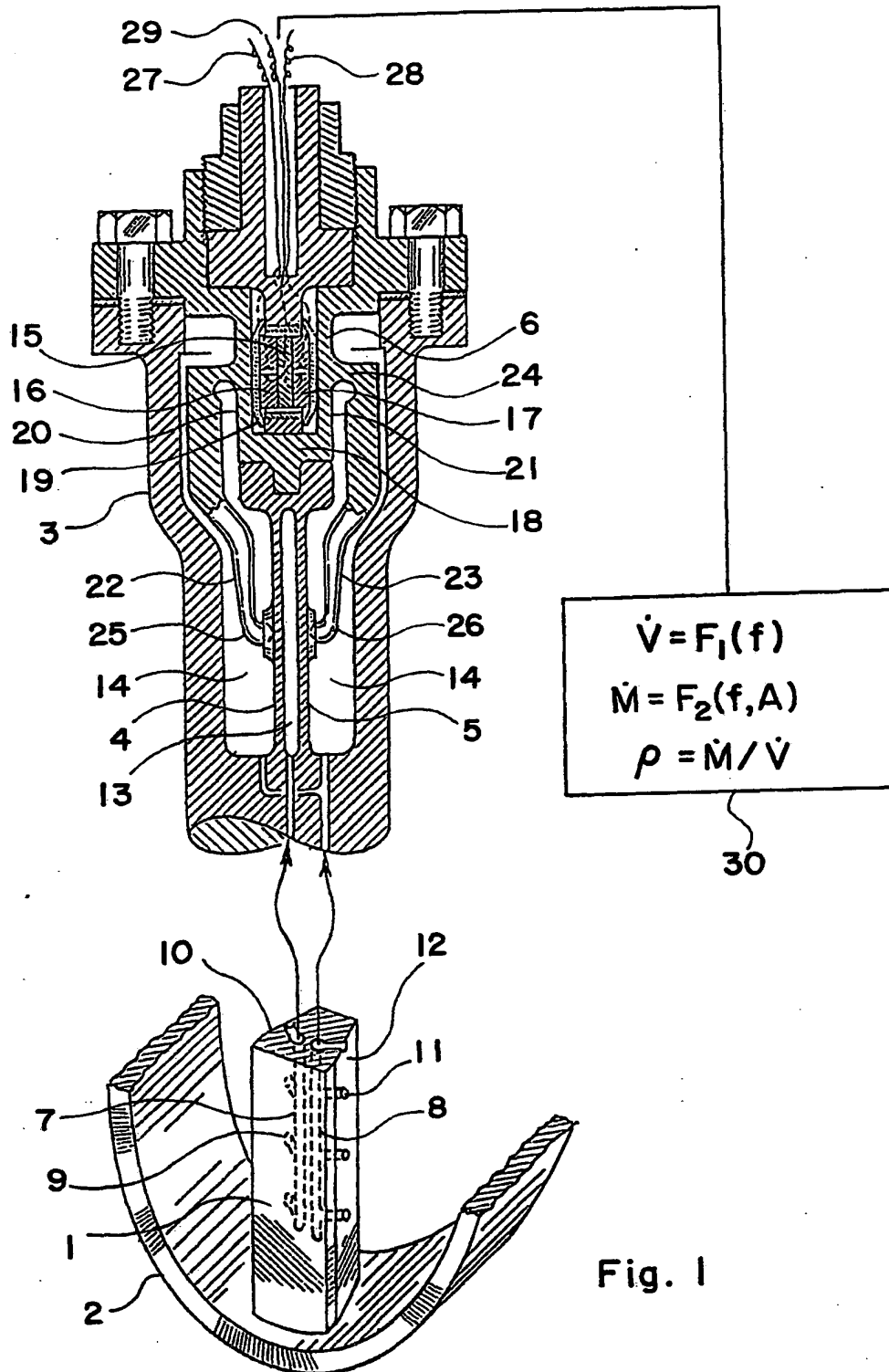
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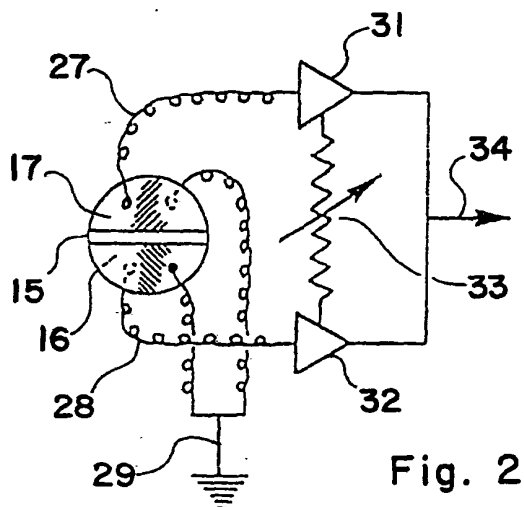


Fig. 2

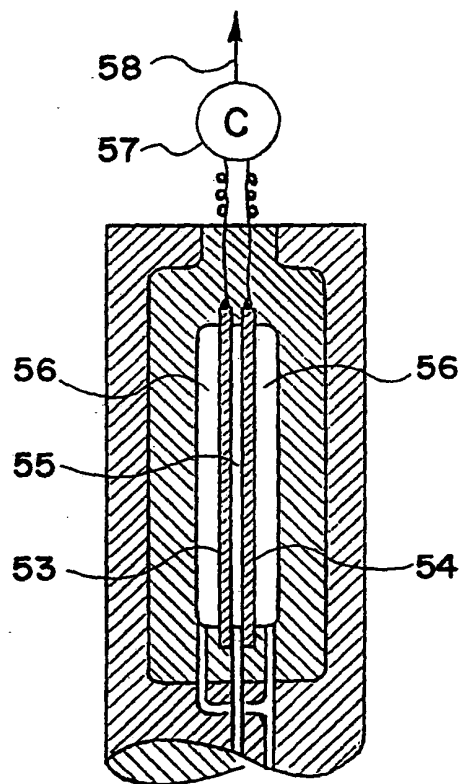


Fig. 4

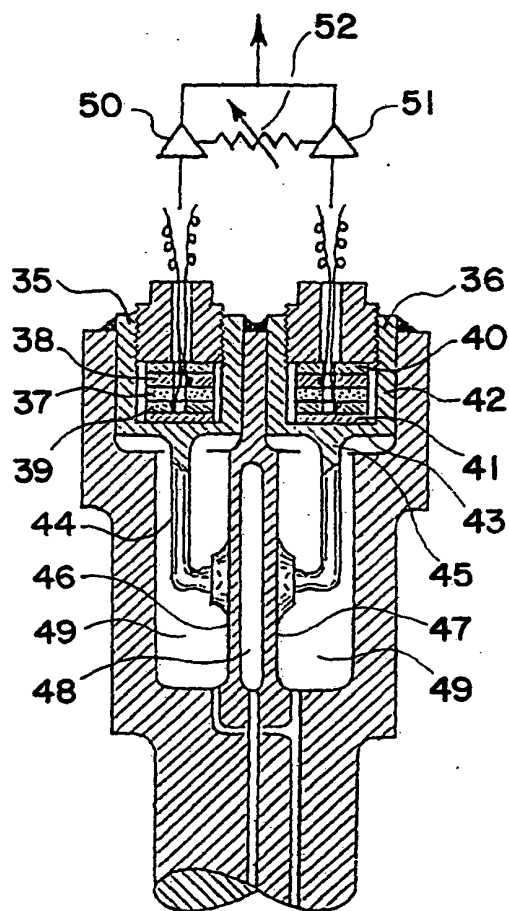


Fig. 3

INTERNATIONAL SEARCH REPORT

PCT/US92/08504

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G01F 1/32

US CL :73/861.24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 73/861.22; 73/861.24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,803,870 (Lew) 14 February 1989	1-9
A	US, A, 4,161,878 (Fussel Jr.) 24 July 1979	1-9
A	US, A, 4,440,027 (Focht) 03 April 1984	1-9
A	US, A, 4,879,909 (Lew) 14 November 1989	1-9

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

07 DECEMBER 1992

Date of mailing of the international search report

05 JAN 1993

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